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Effect of Water Source on Some Engineering Properties of Concrete (Case Study of Lagos Metropolis)

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ABSTRACT: *Lagos city being one of the most populous city in Africa is being faced with scarcity of portable water to meet domestic demand. At the same time there is also an increase in the construction industry with the use of concrete. This has left contractors with the option of seeking different sources of water for concrete production without knowing the effects such water will have on the properties of concrete. Therefore, this investigation critically appraises sources of water use in concrete production as one of the likely causes of building collapse in Lagos city. The performance of six sources of water obtained from Lagos municipality on some engineering properties i.e., setting times of cement paste, compressive strength and split tensile strength of concrete were checked in the laboratory and compared same with controlled specimens that is made with tap water as mixing water and curing water. C25 grade of concrete was adopted with a mix proportion of 1:2:4 at w/c ratio of 0.55. For each mix of water, compressive strength tests were conducted using 150x150x150 mm cube specimens, while tensile strength was investigated using 150x300 mm cylinder specimens. The study revealed that physiochemical properties of water varies depending upon place, time, environment, exposure and storage duration. These physical and chemical composition of water react differently with different constituent of concrete. These reactions mostly affect the setting time of cement paste, compressive strength and split tensile strength of concrete, some favourably while others unfavourably.*

***KEYWORDS**:* *Concrete, setting time, Compressive Strength, Split Tensile strength*

I. INTRODUCTION

Nigeria has witnessed the collapsed of buildings in various dimensions, either those under construction or those already in existences. High death rate during building collapses has been observed in the Nigeria building industry by [1]. The research found that Lagos has the highest causality followed by Abuja. According to Oyenuga [2], one major cause of building collapse includes poor material quality. A major aspect of poor material quality is the incorrect selection of materials for concrete mix. One of which is the usage of improper quality of water both in construction works as well as for curing purposes of concrete. Most concrete structures have either failed prematurely or deteriorated with time due to the presence of deleterious substance present in the water used for their construction. Water is an important constituent of concrete. It chemically reacts with cement to produce the desired properties of concrete. Part of mixing water is utilized in the hydration of cement and the balanced water is required for imparting workability to concrete. Mixing water is the quantity of water that comes in contact with cement, impacts slump of concrete and is used to determine the water to cementitious materials ratio of the concrete mixture. Therefore, the quantity and quality of water is required to be looked into very carefully. According to Reddy and Venkata [3], the use of potable water as the mixing and curing water in concrete has been in used ever since concrete began to be used as a construction material, due to the fact that its chemical composition is well known. [3] further stated that from reviewed literatures not much research work has been carried out on the quality of mixing water in concrete and there are no detailed guidelines in [4 - 6] for the use of water in concrete. Dubey [7] studied the effect of different types of water on compressive strength of concrete and concluded that concrete made with different qualities of water samples such as ground water, packed drinking water, waste water, well water, tap water, etc. have 7- and 28 – day compressive strength equal to or at least 90 percent of the strength of reference specimens made with clean water for M20 grade of concrete. (Except Waste water specimen for 7- day).

A popular criterion to the suitability of water for mixing concrete is that, if water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all condition. Some water containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking [8]. As at the moment there are no special tests developed to determine the suitability of mixing water except comparative tests. Usually, comparative tests require that, if the quality of water is not known, the strength of the concrete made with water in question should be compared with the strength of concrete made with water of known suitability. Both concretes should be made with cement proposed to be used in the construction works. The American Standard ASTM C 94 requires that age of 28 days mortar strengths made with test water to be a minimum of 90% of the strength of cubes made with portable or distilled water. And this approach was employed in this work.

According to [9,10], two measures should be taken into consideration in evaluating the appropriateness of water used for mixing concrete. One of them is whether the impurities in the water from doubtful sources will affect the properties and quality of concrete and the other is the amount of impurity which can be tolerated. These two measures have been considered to some degree in this study. This study analysed the physiochemical properties of water from seven sources within Lagos municipality both when used for concrete mix and when stored and exposed to sunlight. Then, tests were conducted on cement paste and concrete to investigated the effects of water source on setting times of cement paste, compressive strength and split tensile strength of concrete with respect to the study area. The physio-mechanical properties of the parent materials used in making the concrete where analysed as well.

II. METHODOLGY

Materials : In carrying out this study, the following materials were used: cement, fine aggregates, coarse aggregates, and water. The cement used was Dangote 3X, grade 42.5MPa ordinary portland cement that conformed to the standard of [11]. The fine aggregate was river sand gotten from Abeokuta in Ogun State, Nigeria. A washed sand deposit, free from organic matter. The coarse aggregate was granite, a crushed rock and of high quality obtained from a local quarry. Both aggregates met the grading requirement of [12]. The size of the coarse aggregate varied from 2.36mm to 20mm. The water samples used for the research work were obtained from the following sources and labelled as follows: Unilag tap water (Controlled), sample A. Bore hole water from Surulere, sample B. Unilag lagoon water, sample C. Well water from Ajegunle, sample D. Bore hole water from Iwaya, sample E. Well water from Agege, sample F. Bore hole water from Abraham Adesanya, sample G. C25 grade of concrete was adopted with a mix proportion of 1:2:4 at w/c ratio of 0.55. For each mix of water 15 cubes (150mm x 150mm x 150mm) and 10 cylinders (300mm x 150mm diameter) were cast. All cubes and cylinders were tested in the laboratory at five curing days- 7, 14, 28, 45 and 96 days.

Method: The following pertains to some laboratory procedures carried out in this report.

Physical and Chemical Analysis of Materials : Laboratory tests carried out on the aggregates include particle size distribution, specific gravity, dry and bulk densities, and moisture contents. Specific gravity test was carried out on the cement as well. The physiochemical properties of the different water sample were determined at the Centre Research Lab and the Civil & Environmental Engineering Water Lab at the University of Lagos, Nigeria.

Setting Times Tests : The setting times (initial and final) were carried out in accordance to [11], using the Vicat probe and the Vicat needle apparatus.

Compressive Strength Test : Compressive strength gained was determined for all samples by using a compression testing machine in accordance with [13]. The test specimens were

$15 \times 150 \times 150mm$ concrete cube. Three specimens for each mix were loaded to failure at 7, 14, 28, 45 and 96 curing days. The maximum load sustained by the specimens were recorded and the average compressive strength of the samples were calculated.

Tensile Strength Test : The splitting tensile strength test was conducted on 150 x 150 x 300mm concrete cylinder specimens in accordance with the provision of [14]. Assuming concrete specimen behaves as an elastic body, a uniform lateral tensile stress of f_t, acting along the vertical plane causes the failure of the specimen, which can be calculated from the formula as,

$$f_t = \frac{2P}{\pi DL}$$

P = Compressive load at failure

L = Length of cylinder

D = Diameter of cylinder

III. RESULTS AND DISCUSSIONS

Physical Properties and sieve analysis : The physical properties of materials used in this investigation are presented in Table 1. The results in table 1 showed that the average specific gravities of sand and granite are 2.67 and 2.70 respectively, these results fall within the lower limits for natural aggregate which have specific gravities between 2.6 and 2.7 Neville [15], both the fine and coarse aggregate conform to [16]. The average bulk densities for both sand and granite were found to be 1497.6 kg/m³ and 1558.6kg/m³ respectively. This clarified both the fine aggregate (sand) and the coarse aggregate (granite) as normal weight aggregates based on [17]. The cement used in this research has a specific gravity of 3.14 which is in conformity to [11].

Table 1. Physical properties of aggregates and cement

PROPERTY	GRANITE	SAND	CEMENT
Specific Gravity	2.70	2.67	3.14
Bulk Density	1558.6kgm^{-3}	1497.6kgm^{-3}	-
Dry Density	1553.6kgm^{-3}	1429.1kgm^{-3}	-
Fine Modulus	5.14	4.69	-
% Fineness passing through 90μmm	-	-	99.5
Moisture content	0.32%	4.79%	-
Silt content	0.5%	0.01%	-
Aggregate Impact Value Test	10.38%	-	-
Aggregate Crushing Value Test	17.07%	-	-
Coefficient of Uniformity (C_u)	1.26	2.67	-
Coefficient of Curvature (C_c)	1.07	1.00	-

Physiochemical Properties of Water Used in Concrete Mix and Curing and exposed to sunlight: Results in table 2 were compared to the permissible limits in [18] for the use of non-portable water for concrete production. It can be seen that all the sources of water were within the prescribed limit. However, in comparison to the WHO [19] and Nigerian [20] standards of drinkable water, well water from Ajegunle and bore hole water from Iwaya are the worst type of non-portable water, while well water from Agege and bore hole water from Surulere are the best form of non-portable water. Surprisingly enough tap water from Unilag failed to meet some limits in [19 & 20]. Table 3 shows the physiochemical properties of water exposed to sunlight with the exception of the heavy metal ions. The result tabulated in table 3 clearly indicate increase in the values of the conductivity, TDS, calcium hardness, total hardness and pH with increase in temperature, while a decrease is recorded in salinity, chlorides, acidity, alkalinity, colour and sulphate when stored and exposed to sunlight for a period of 45 days. The study revealed that storage duration and exposure affect the physiochemical properties of water. It can be deduced that water is susceptible to being changed due to physical, chemical or biological reactions which may take place at the time of storing and exposing. Hence it is necessary to test water before using it for concrete production.

Table 2. Physiochemical properties of water samples used in concrete mixed

PARAMETER	WATER SAMPLES						
	A	B	C	D	E	F	G
pH	6.4	6.2	6.3	6.0	6.1	6.2	5.0
Temperature ($°C$)	27.4	27.5	27.5	26.6	27.0	27.3	27.4
Salinity (ppm)	72	130	160	680	2830	170	420
Conductivity ($uscm^{-1}$)	170	300	340	1394	4660	380	520
TDS (mg/l)	125	219	245	975	3530	273	378
Chloride(mg/l)	64	104	140	288	2648	128	320
Calcium Hardness (mg/l)	48	40	64	228	152	76	80
Total Hardness (mg/l)	60	80	108	376	580	88	108
Acidity (mg/l)	12	20	16	24	16	20	28
Alkalinity (mg/l)	20	36	96	140	36	20	36
Sulphate (mg/l)	60	60	90	100	180	55	70
Colour (pcu)	179	110	792	197	57	62	61
Calcium (mg/l)	7.5	8.36	8.86	25.45	6.94	7.54	5.79
Manganese (mg/l)	0.32	0.44	0.33	0.04	0.45	0.10	0.18
Copper (mg/l)	0.54	0.54	0.54	0.46	0.44	0.46	0.47
Zinc (mg/l)	3.76	3.51	5.62	1.44	0.25	0.44	0.17
Lead (mg/l)	0.12	0.05	ND	0.08	0.03	0.02	0.01
Iron (mg/l)	14.98	12.52	108.3	4.62	2.83	3.88	3.38
Cadmium (mg/l)	0.04	0.06	0.21	0.05	0.05	0.07	0.17

Table 3. Physicochemical properties of water samples (bottled) exposed to sunlight after 45 days with the exception of the heavy metal ions.

PARAMETER	WATER SAMPLES						
	A	B	C	D	E	F	G
pH	7.1	6.9	6.8	6.8	6.6	6.9	6.0
Temperature ($°C$)	28.7	28.8	28.8	28.7	28.7	28.7	28.8
Salinity (ppm)	40	110	160	670	2530	168	270
Conductivity ($uscm^{-1}$)	173	304	324	1422	4795	392	555
TDS (mg/l)	128	213	250	995	3630	281	392
Chloride(mg/l)	60	98	132	284	2528	120	192
Calcium Hardness (mg/l)	52	53	70	332	152	120	92
Total Hardness (mg/l)	68	100	120	412	808	116	148
Acidity (mg/l)	8	16	12	13	14	12	20
Alkalinity (mg/l)	56	48	84	88	48	16	28
Sulphate (mg/l)	45	40	60	65	150	35	50
Colour (pcu)	42	65	279	135	51	55	47

Effect of water source on setting times of cement: From figure 1 it is observed that the initial and final setting time of cement paste were found to be within the prescribed limits of [21] in spite of the type of water source. However, it was observed that the setting time of the ordinary portland cement varies with the type of water mix. It is shown that Unilag tap water (portable water) has the least initial and final setting times of 131 and 171 minutes respectively while bore hole water from Abraham Adesanya (non-portable water) recorded the highest initial and final setting times of 158 and 191 minutes respectively.

Effect of water source on compressive strength of concrete : From figure 2, it is observed that the compressive strength increased with increase in curing age when mixed with all test waters. On the basis of compressive strength analysis water from Unilag tap (controlled) recorded $31.11Nmm^{-2}$ which is the highest while bore hole water from Abraham Adesanya recorded $17.04Nmm^{-2}$ which is the lowest after 96 days of curing. The results showed that concrete made with non-portable water from bore hole water from Iwaya, Unilag lagoon, well water from Ajegunle, bore hole water from Surulere, well water from Agege and bore hole water from Abraham Adesanya have 7- and 28 – day compressive strength equal to 99.6% & 99%, 92% & 91%; 90% & 88%, 88% & 85%, 79% & 73% and 51% & 50% of the strength of controlled specimens made with Unilag tap water respectively. This implies that only water from Iwaya bore hole and Unilag lagoon met the prescribed limit for 7- and 28- day compressive strength (90% of controlled specimen). This implies that the use of non-potable water yields lower compressive strength in comparison to concrete made with potable water.

The Target strength of $25N/mm^2$ at 28 days was only met by Unilag tap water and bore hole water from Iwaya, on the other hand the other non-portable waters have a ranged from 53% - 96% of the target strength at

28 days. However, when the curing duration was extended to 96 days, the concrete cubes produced strength that surpassed the target strength (except for well water from Agege and bore hole water from Abraham Adesanya).

Effect of water source on split tensile strength of concrete : From figures 3, the test results showed that the split tensile strength increased with increase in curing period when mixed with all test waters. On the basis of split tensile strength analysis water from Unilag tap (controlled) recorded $2.26\ Nmm^{-2}$ which is the highest while bore hole water from Abraham Adesanya recorded $1.49\ Nmm^{-2}$ which is the lowest after 96 days of curing. The result showed that the use of non-potable water yields lower split tensile strength in comparison to concrete made with potable water.

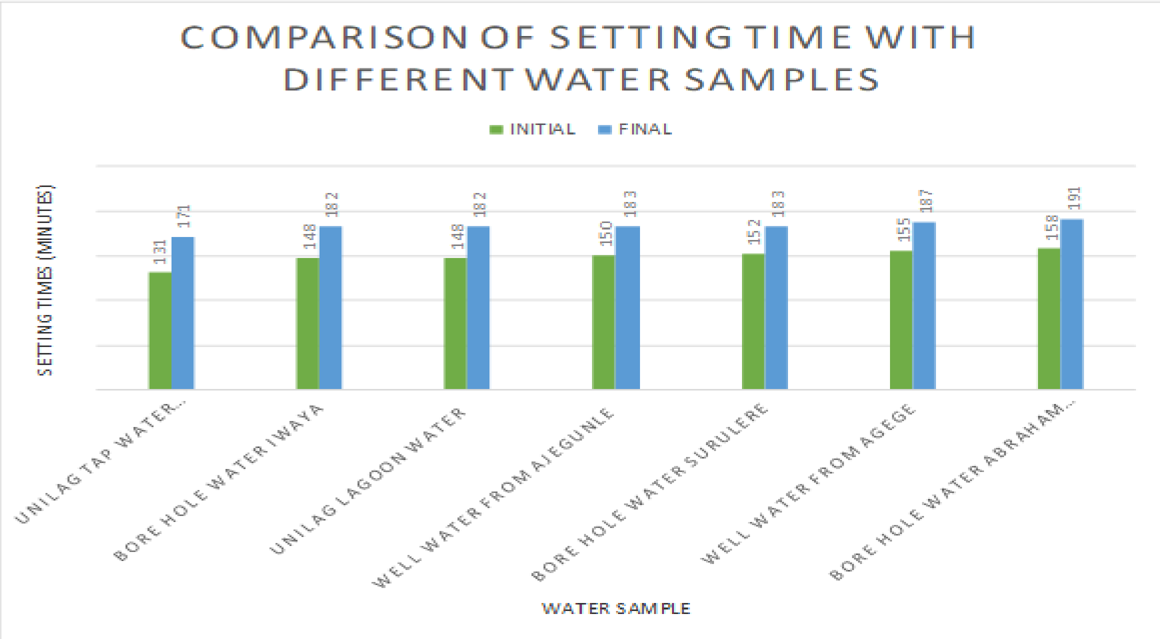

Figure 1. Setting time with different water samples

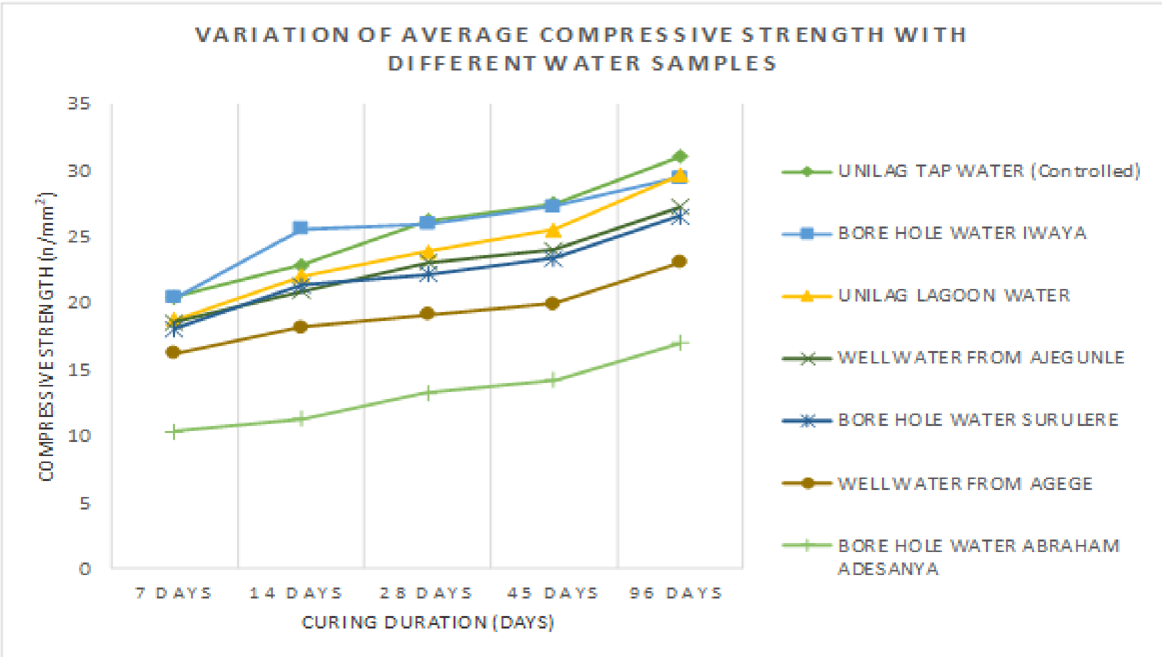

Figure 2. Variation of Average Compressive strength with different water samples at different curing ages

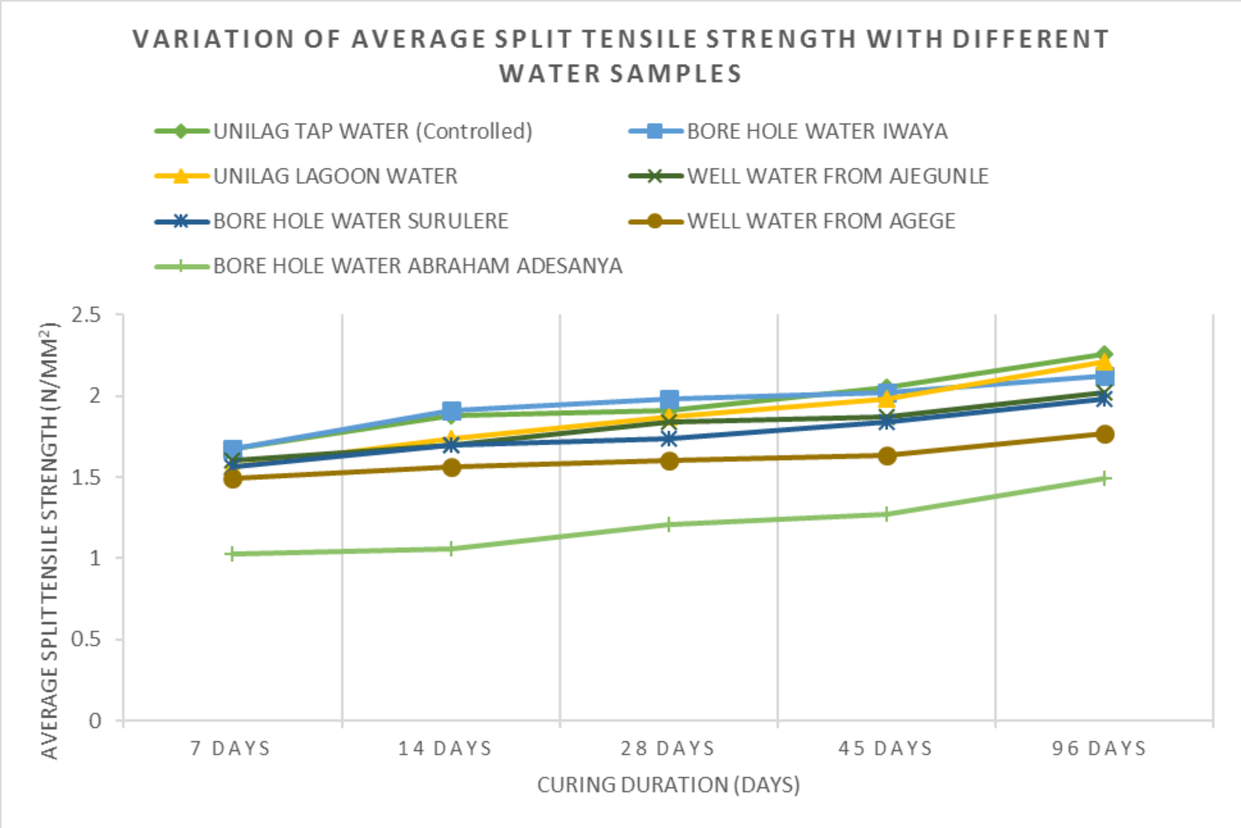

Figure 3. Variation of Average Split tensile strength with different water samples at different curing ages

IV. CONCLUSIONS

The results of this investigation carried out showed a continuous increase in strength for the compressive and split tensile strength when cured at the different curing days of 7, 14, 28, 45 and 96 days for the cubes and cylinders in spite of the source of water used. It can therefore be concluded that:

I. the use of non-potable water yields lower compressive strength and split tensile strength in comparison to concrete made with potable water.

II. the setting time of ordinary portland cement varies with the type of water used which is consistent with the findings of [22], who specified that from studies, the setting time of ordinary portland cement is mostly affected by the type of water.

III. physiochemical properties of water vary depending upon place, time, environment, exposure and storage duration. These physical and chemical composition of water react differently with different constituent of concrete. These reactions mostly affect the setting time of cement paste, compressive strength and split tensile strength of concrete, some favourably while others unfavourably.

VI. the higher the setting time, the lower the strength of concrete produced which is in accordance with the result of Mbadike et al. [23], who using fresh and salt water samples discovered that at a steady increase in setting time, the lower the strength of concrete is produced.

VII. The times of setting of portland cement mixtures containing non-portable water were found within the prescribed limits of [21] Part 3 in spite of the type of water source. However, only water from Unilag lagoon met the prescribed limit for 7- and 28- day compressive strength (90% of controlled specimen). The tests showed that setting time is not a satisfactory test for suitability of a water for mixing concrete. Hence it is recommended that on-site testing of concrete and its constituents especially water should be carried out since it has been observed that laboratory tests are well planned for.

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